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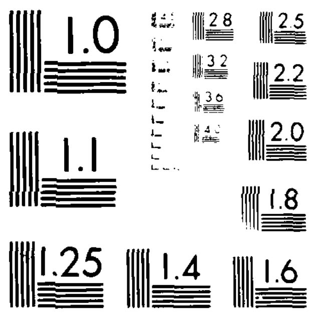

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EFFECTS OF REPETITIVE, SMALL-SPOT, INCOHERENT LIGHT FLASHES ON PURSUIT TRACKING PERFORMANCE

RICHARD R. LEVINE, PhD, CPT MSC
PETER A. O'MARA, PhD, MAJ MSC
DAVID A. STAMPER, MA
JEROME W. MOLCHANY, BS, SP5
and
DAVID J. LUND, BS

DIVISION OF OCULAR HAZARDS

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Effects of Repetitive, Small-Spot, Incoherent Light Flashes on Pursuit Tracking Performance--Levine et al

Human Subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Reg 50-25 on the use of volunteers in research.

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The effects of repetitive, small-spot incoherent light flashes on pursuit tracking was studied in the BLASER tracking simulator under bright and dim ambient light conditions. Ten experimentally naive men served as volunteers. The target was a scale-model tank moving at a constant angular velocity of 5 mrad/sec at a simulated distance of 1 km. A series of 5 flashes, presented at a rate of 20 Hz, were presented during randomly selected tracking trials. Flashes were produced with a miniature xenon flash lamp housed within the tracking

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device and spatially filtered to produce a 100μ retinal diameter spot at approximately 50% of the maximum permissible exposure level. Colored filters in front of the lamp were used to produce flashes in the red and green portions of the spectrum. Unfiltered light from the lamp produced white-light flashes.

The flashes produced statistically significant increases in the horizontal standard deviation error scores. These were manifested mainly by lead or lag errors (crosshairs ahead or behind the target) in response to the flash, followed by a return to baseline error levels. The magnitude of this effect was greater in the dim viewing condition than in the bright, as measured by maximum aiming error and the temporal course of recovery. No significant effect was observed for flash color, -- equal energy red, white, and green flashes producing similar postflash performance changes.

ABSTRACT

The effects of repetitive, small-spot, incoherent light flashes on pursuit tracking was studied in the BLASER tracking simulator under bright and dim ambient light conditions. Ten experimentally naive men served as volunteers. The target was a scale-model tank moving at a constant angular velocity of 5 mrad/sec at a simulated distance of 1 km. A series of 5 flashes, presented at a rate of 20 Hz, were presented during randomly selected tracking trials. Flashes were produced with a miniature xenon flash lamp housed within the tracking device and spatially filtered to produce a 100μ retinal diameter spot at approximately 50% of the maximum permissible exposure level. Colored filters in front of the lamp were used to produce flashes in the red and green portions of the visible spectrum. Unfiltered light from the lamp produced white light flashes.

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PREFACE

We express thanks to SP4 Kenric Silva for his technical support during the extensive data collection phase of the project. We would like to thank Victor Pribyl, Ken Bloom, and COL E.S. Beatrice, MC, for their comments and critical review of this manuscript. Also, we would like to thank Christina Vancheri for her excellent graphics. We are also indebted to *Virginia Gildengorin, PhD*, for her valuable assistance in the statistical evaluation of the data and to Lettie Applewhite for expert editorial improvements.

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EFFECTS OF REPETITIVE, SMALL-SPOT, INCOHERENT LIGHT FLASHES ON PURSUIT TRACKING PERFORMANCE--Levine et al

The effects of bright light flashes on military performance have been extensively investigated (e.g., 1,2). For the most part, these studies have been conducted with aviator personnel in flight simulators to document the debilitating visual effects resulting from environmental "white-out" following simulated nuclear detonation. Typically, high-intensity, full-field, single-pulse, white light flashes, of several milliseconds or longer duration, have been used to produce visual dysfunction (from the initial flash exposure and resulting afterimages) and the effectiveness of this disruption gauged by measuring the latency to complete some visual performance task (e.g., correctly reporting a feature on an instrumental panel). The exposed retinal areas have been generally many times greater than that of the stimulus targets.

Ground troops engaged in combat may also be exposed to high intensity light which could disrupt the successful completion of their military mission. Pyrotechnics, high-intensity search lights, and electronic strobes are all capable of producing visual disturbances which could compromise both unaided-eye and daysight viewing, especially under low-light conditions. Lasers may represent an additional battlefield threat. Enemy forces could exploit the exceptional brightness, accurate aiming, and nanosecond (10^{-9} sec) delivery properties of lasers by deliberately engaging and optically countermeasuring soldiers (3). Visible and near infrared laser energy collected and amplified through magnifying daysight optics and received by the eye could result in permanent retinal damage with accompanying long-term visual dysfunction (4). Lower-level, non-damaging exposures, delivered before the onset of the blink reflex, could result in temporary flash blindness and adversely impact mission performance.

Previous work from this laboratory examined the effects of chromatic strobe flashes on pursuit tracking performance with a viscous-damped mount tracking device (5). Single-pulse, 538 nm - centered (green) strobe flashes, almost 10 times below maximum permissible safe exposure levels (and much lower than levels produced by many military laser devices), were delivered to volunteers tracking highly predictable moving targets. Flashes were full-field and exposed a retinal area with a diameter of approximately 30 degrees. The flashes produced significant disruptions of pursuit tracking performance, as measured by increases in both horizontal and vertical

post-flash standard deviation error scores, under both bright and low ambient light conditions.

An important aspect of laser radiation from currently fielded systems is the characteristic of low beam divergence, i.e., a very small beamspread with relatively little light loss over typical tactical distances of 1 to 2 km. Focusing of the laser radiation by the eye would produce retinal exposures no greater than [illegible] to 70 microns in diameter and encompass an area many times smaller than that produced by a magnified view of the target [illegible]. In addition [illegible] tactical lasers may operate in a pulse [illegible] or [illegible] wavelengths in the visible energy region. The [illegible] study [illegible] therefore designed to examine the effects of [illegible] low-level laser exposure, i.e., repetitive, small-spot ([illegible] μ retinal image diameter), white light and chromatic flashes, on pursuit tracking performance under both bright and dim ambient lighting conditions.

METHODS

Volunteers. Ten experimentally naive men (9 active duty [illegible] and 1 Department of the Army civilian), ranging in age from [illegible] to [illegible] years (average = 29 yr), served as volunteers. Each volunteer [illegible] administered a battery of clinical visual tests and provided [illegible] ophthalmological examination before and after the study. The clinical battery included the Farnsworth-Munsell 100-Hue Test, the Ishihara Test for Color Blindness (Kanehara Shuppan Co., Tokyo, Japan, 1969) the Arden Test of Contrast Sensitivity, and dark-adaptation testing. All participants were judged to be within normal limits on both screenings before and after the study. Before any experimental or clinical procedure, each participant was briefed on the purpose of the study and was requested to sign a volunteer consent form (Appendix [illegible]).

Procedure. Pursuit tracking performance data was collected under simulated field conditions in the BLASER tracking simulator (7). The simulator consisted of a scale model Warsaw Pact T-62 tank target on a terrain board and a full-sized sandbag bunker which housed the viscous-damped optical tracking device. The target was track-mounted and driven in a single direction from left to right at a constant angular velocity of 5 mrad/sec. The track was laid out over a level course at a constant arc from the center post of the tracking device at a simulated distance of 1000 meters. Trials commenced with the target stopped and the observers' crosshairs aligned with a 0.5 mrad aiming patch located centrally between the turret and hull of the tank. On the command, "Ready -- Go," the target traversed the terrain for approximately 15 sec while the operator attempted to keep the crosshairs fixed on the target. An infrared light-emitting diode, located in the center of the aiming patch, was imaged by a television camera mounted coaxially with the optics of the tracking device. Invisible to the operator, its signal provided a reference point source for a microprocessor and associated software to monitor

tracking performance electronically.

Flashes were produced with a miniature xenon flash lamp (EG&G No. 27[illegible]) also housed within the tracking device. The light-emitting area was focused and spatially filtered to produce a [illegible] retinal diameter spot size and boresighted to the center of the operator's crosshairs. To the volunteer engaged in target tracking, the flash appeared to originate from the tank and cover an area no larger than the bull's-eye of the target's aiming patch. A flash trial consisted of five, 2 μsec pulses, occurring at a rate of 20 pulses/sec. Chromatically unfiltered light from the lamp was used to produce "white" light flashes. Kodak Wratten filters were used to obtain flashes within the red (No. 26) and green (No. 58) portions of the visible spectrum. These colors were chosen to represent currently or potentially fielded visible wavelength laser systems. Using the radiant energy output obtained with the red filtered light as a standard, neutral density filters were used with the unfiltered and green filtered light to produce approximately equal output energies between flash conditions. Measured dosimetry of the energies were calculated to be nearly 10 times below maximum permissible energy levels for human exposure (8). At no time during the course of the study were volunteers exposed to laser radiation.

Ambient terrain lighting was controlled by inserting or removing a separate neutral density filter within the optics of the tracking device. Using a Spectra Minispot photometer, the measured average terrain luminance at the exit aperture of the tracking device was 250 lm/m^2 under bright light conditions. Under low-light, with the neutral density filter in place, luminance was calculated to be 0.8 lm/m^2. This level was chosen to represent an early dawn/late dusk condition. Light was permitted to enter the bunker only from the optics of the tracking device or from an overhead diffused incandescent bulb. During the bright-light condition, average ambient luminance within the bunker was 5.0 lm/m^2. The bunker lights were turned off during low-light trials.

Each volunteer received four daily, 30-trial training sessions prior to test day. Half of the trials were conducted under each of the 2 ambient lighting conditions. A 1-min rest period was provided between each trial and a 10-min rest break was permitted between each block of 15. An additional 10 min was permitted for partial dark adaptation before tracking under the low-light condition. Summary feedback information, in terms of percent time on target and horizontal standard deviation scores was provided to volunteers following the completion of each tracking trial. In previous studies, these training conditions have yielded stable operator tracking performance with a high level of operator accuracy. A single experimental session, identical to the training sessions except for the insertion of flash trials, was administered on the day following

the completion of training. On both training and test days, half the volunteers started under bright-light and half under low-light conditions; the order was alternated for each group on each day.

Flash trials occurred randomly at the rate of 1 per 5 tracking trials. In all, 6 flash trials out of a total of 30 tracking trials were presented to each subject on test day. Thus, 3 trials, 1 of each color, were presented in each block of 15 bright and low-light trials. Flashes were either white, red, or green light, with the orders of the colors both random and exhaustive (i.e., a specific color could not be used again until the remaining colors were presented). Before testing, volunteers were briefed concerning the use of flash exposure, but they were unaware of the schedule, colors, or number of flash presentations to be used. Embedded randomly within each block of 15 trials under each lighting condition was a control trial identical to a flash trial except that the output of the flash lamp was blocked by an opaque screen. (However, the auditory component of the lamp's discharge, a faint "ticking" sound, was still present.) Flashes occurred from 5 to 10 sec within each trial run.

Statistical Design and Analysis For both flash and control trials, standard deviation (variable) error scores were derived from the digitized time series (at a rate of 20 samples/sec) of the horizontal and vertical aiming errors. A 5-sec sample period centered around the flash onset was used for the initial analysis of flash effects. By using the mean variable horizontal and vertical tracking errors, separate t-tests for correlated samples were performed to evaluate the 2.5 sec pre- and post-flash mean differences under both bright or low-light conditions for the control and chromatic flash trials (N=10 for each condition). Maximum absolute horizontal and vertical aiming errors before and after flash were also recorded and compared. An analysis of variance (ANOVA) was used to evaluate pre/post variable error scores as a function of ambient-lighting condition and flash color. The ANOVA was performed with the BMDP-2V program for multifactorial mixed designs (9). The ANOVA was based upon a fixed-effects model with repeated measures on both factors. The 0.05 level of significance was used for the analyses of all the data.

Recovery of normal performance was estimated by plotting average absolute (lead/lag) errors for each flash/lighting condition for all subjects for the 5-sec period following flash onset and visually inspecting the time at which the average error returned to baseline rates (the 2-sec period before the flash).

RESULTS

Individual Trials. Figures 1a through f are examples of individual tracking trials for several volunteers under bright (Figures 1a, b, and c) and dim (Figures 1d, e, and f) ambient light conditions. Each figure is a temporal representation of crosshair location along the horizontal and vertical axes with respect to the center of the aiming patch. (Because elevation errors are considerably smaller than those along the azimuth, vertical error scales have been expanded to provide greater clarity.) Figures 1a through d are trials in which a small spot flash occurred during the tracking run. Figures 1e and f illustrate control trials during which the flash was not visible to the operator. Performance on control trials for all volunteers was indistinguishable from performance on non-flash trials.

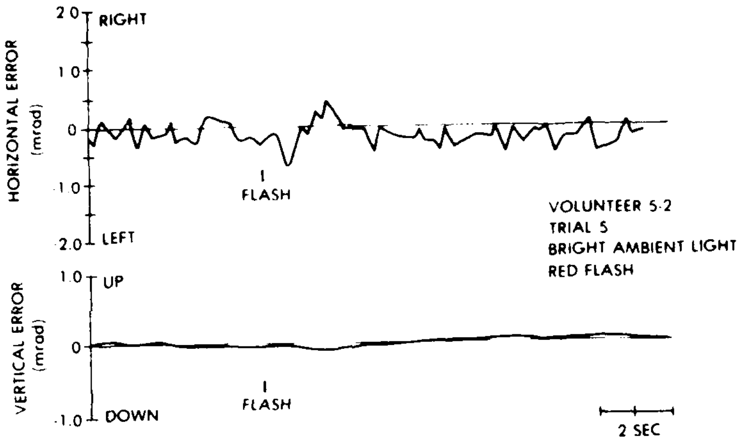

Figure 1a. Bright ambient light: Red flash.

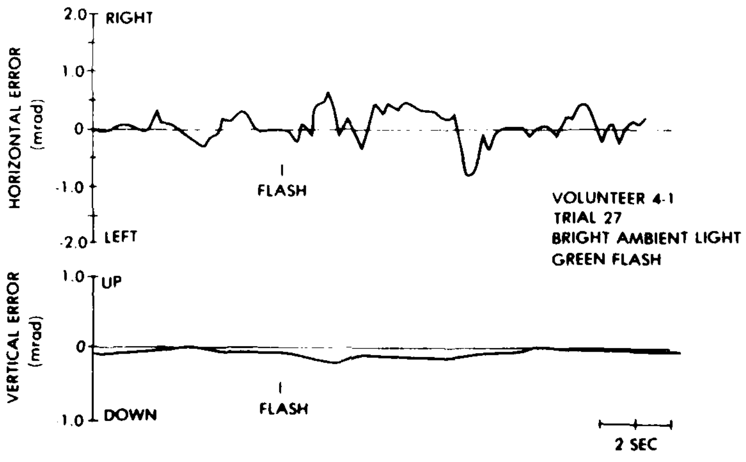

Figure 1b. Bright ambient light: Green flash.

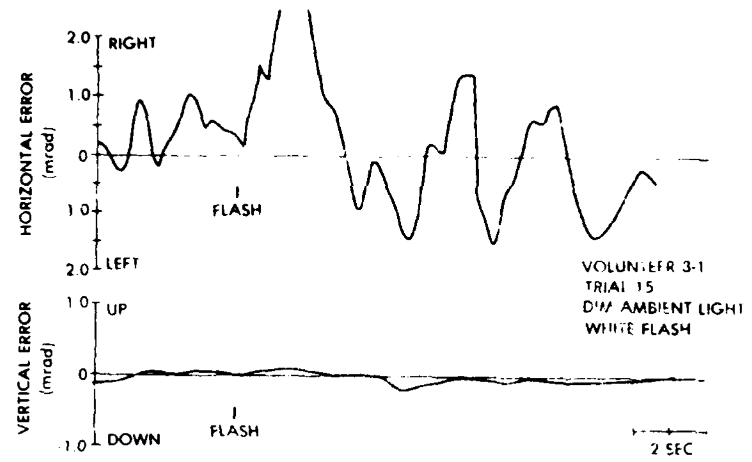

Figure 1c. Dim ambient light: White flash.

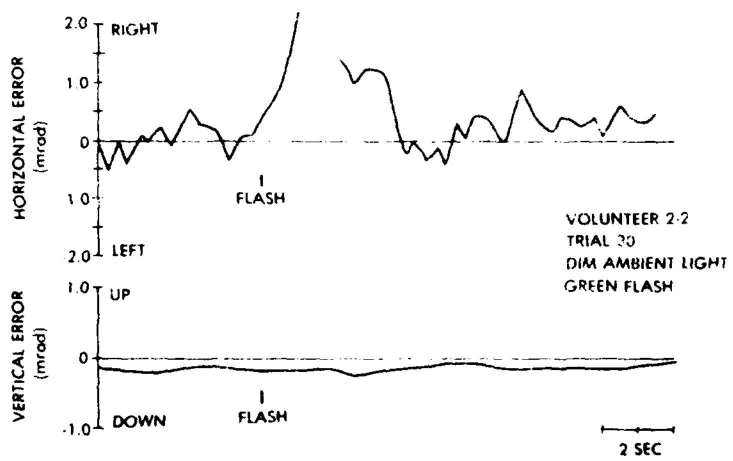

Figure 1d. Dim ambient light : Green flash.

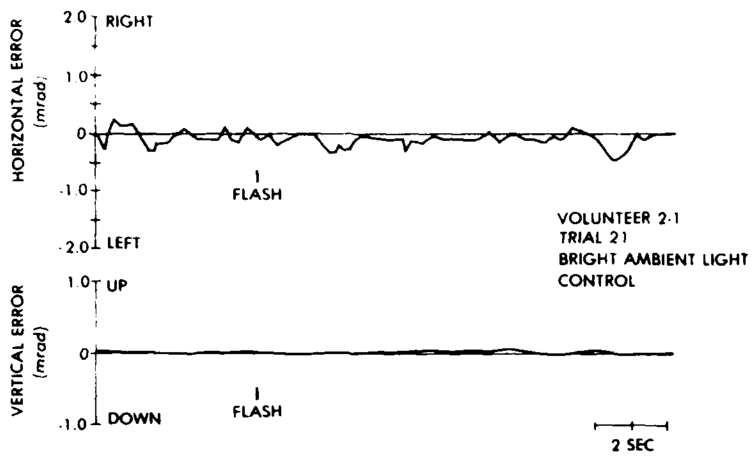

Figure 1e. Bright ambient light: Control trial.

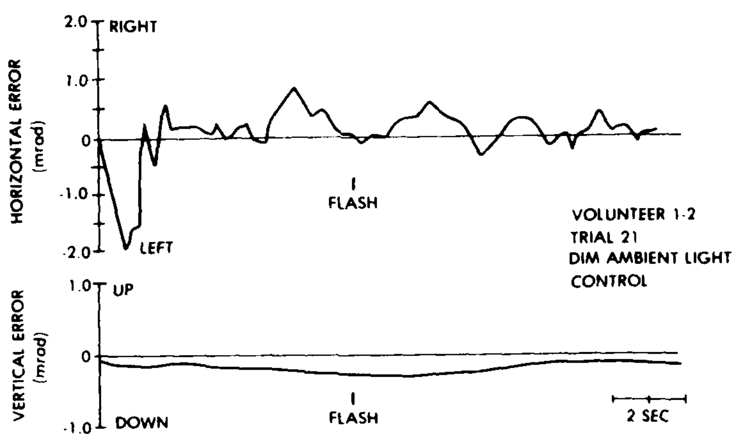

Figure 1f. Dim ambient light: Control trial.

The data in Figures 1c and d were obtained under low-light conditions from two volunteers and were deliberately chosen to illustrate "worse case" (i.e., maximal) flash effects. In both cases, the (green or white) flash produced off-scale (i.e., >2.5 mrad from target center) excursions of the crosshairs in the direction of target movement (left-to-right). There were no obvious changes in the vertical error component in these or any other cases. Performance returned to pre-flash error levels after 2 to 4 sec. The effects of the same flash conditions under bright light in two additional volunteers are shown in Figures 1a and b. Effects were again produced primarily along the horizontal axis but were dramatically attenuated. Resumption of baseline error performance rates in both cases was within 2 sec.

Horizontal Error. The results of the horizontal standard deviation (SD) error scores for the 2.5 sec interval before and after flash onset are shown in Figure 2 and summarized in Table 1. Group means for each flash condition under each ambient light level are shown in Figure 2 by filled circles; surrounding bars represent ± 1 SD around the mean. Median scores, indicated by horizontal lines within the bars, are also presented for purposes of comparison.

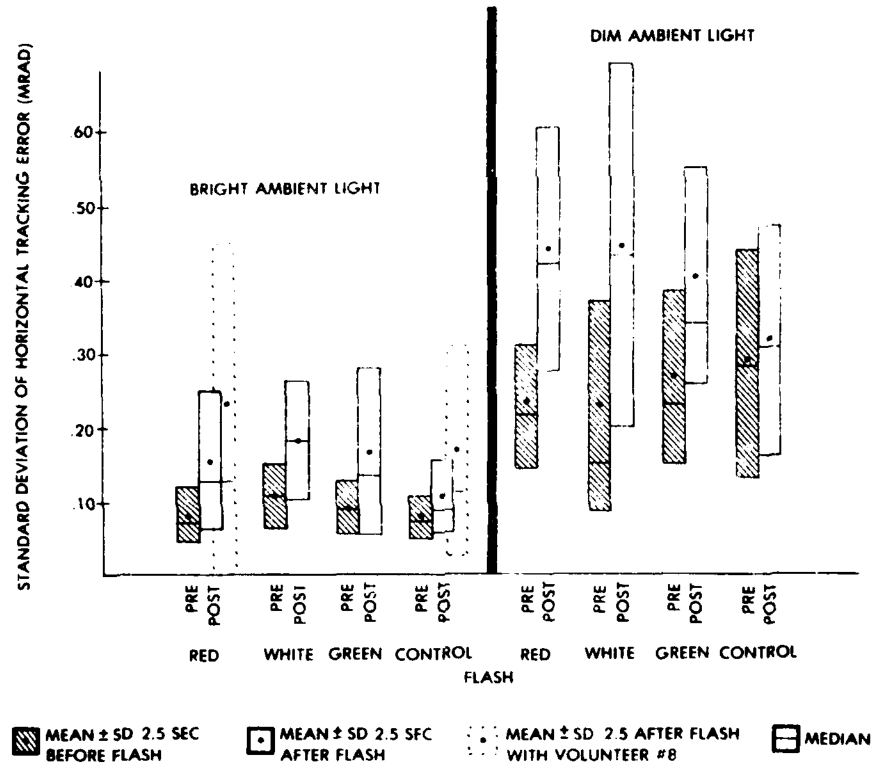

Figure 2. Horizontal SD error scores: 2.5 sec pre/post interval.

In general, the values for the means, medians, and SDs presented in Figure [illegible] were calculated from the combined data of all ten volunteers. However, under bright ambient light, the post-flash statistics for both the red and control flash conditions were plotted with (broken bars) and without (solid bars) the data from Volunteer 8. This volunteer was treated as an outlier because his post-flash scores fell beyond two SDs of the group mean. The inclusion or omission of his scores had practically no effect on the calculated pre-flash statistics or on the subsequent analysis of the data.

The results of the paired t-tests for pre/post mean differences under bright and dim ambient light conditions are presented in Table [illegible]. Under the bright ambient light condition there is a small, but statistically significant ($p<.05$), increase in post-flash variable error for the white and green flash conditions. (Red and control conditions yielded non-significant differences with or without data from Volunteer 8.) Under dim ambient lighting, the pre/post mean horizontal variable error difference was statistically significant for all but the control flash condition. The increased horizontal SD tracking error and associated variability observed under low light is consistent with data from previous studies (10).

TABLE 1

Summary of Paired t-tests for Horizontal Error
Pre-Post Mean Differences Under Bright and Dim
Ambient Light Conditions*

FLASH COND	PRE MEAN	SD	POST MEAN	SD	MEAN DIFF	DF	t-value	PROB †
BRIGHT AMBIENT LIGHT								
RED	.082 (.083)‡	.037 (.039)	.229 (.157)	.244 (.095)	.15 (.07)	9 (8)	1.94 (.05)	NS (NS)
WHITE	.105	.046	.180	.081	.07	9	2.29	<.05
GREEN	.088	.039	.166	.113	.08	9	2.23	<.05
CONTROL	.074 (.076)	.025 (.029)	.168 (.132)	.143 (.049)	.09 (.09)	9 (8)	2.06 (1.70)	NS (NS)
DIM AMBIENT LIGHT								
RED	.232	.079	.441	.164	.21	9	4.25	<.05
WHITE	.227	.144	.443	.243	.22	9	2.3	<.05
GREEN	.267	.117	.403	.147	.24	9	2.6	<.05
CONTROL	.286	.153	.318	.155	.03	9	0.51	<.05

* *The analysis was performed using Biomedical Computer Program 2V.*

† The P<.05 level was used to determine statistical significance.

‡ Data with Volunteer 8 scores excluded.

Vertical Error. The results of flash on the vertical SD error scores are summarized in Figure 3. For comparison purposes, the standard deviation bars around the vertical SD error means are drawn to the same scale as the horizontal. Overall, the relative vertical variable error levels are considerably smaller than those along the azimuth, an expected outcome considering the primarily horizontal nature of the tracking task. Likewise, the lack of a vertical component to the tracking task is reflected in the results of the paired t-tests - no significant pre-post differences for any of the flash conditions (Table 2). The differences seen in the control and white flash condition under low light ($\bar{d}$ = .[illegible] mrad, $p<.05$) are of a statistical nature only and of no practical significance. No further analyses were therefore performed on the vertical error data.

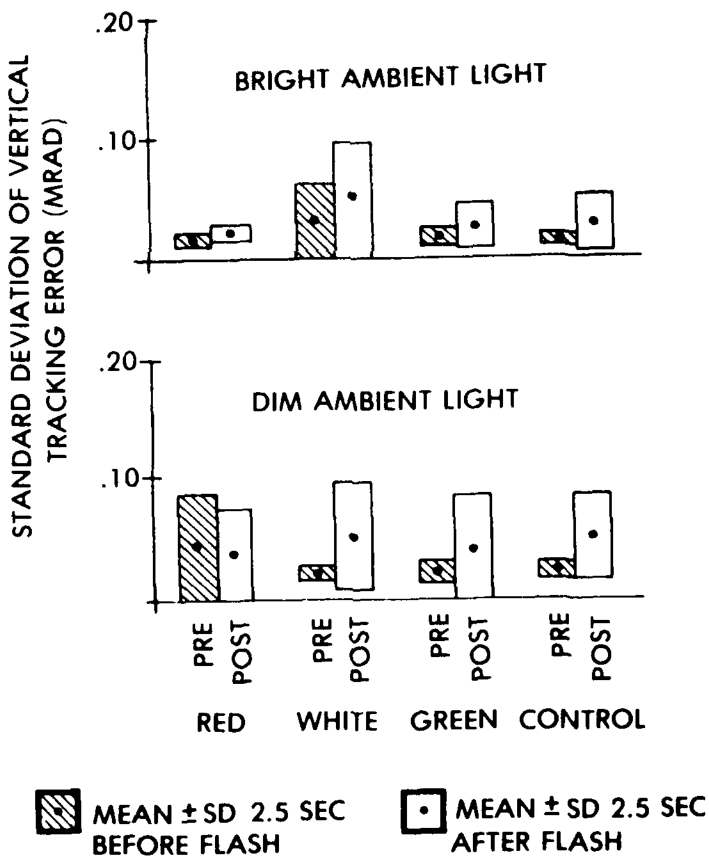

Figure 3. Vertical SD error scores: 2.5 sec pre/post interval.

TABLE 2

Summary of Paired t-tests for Vertical Error
Pre-Post Mean Differences under Bright and Dim
Ambient Light Conditions*

FLASH COND	PRE MEAN	SD	POST MEAN	SD	MEAN DIFF	DF	t-value	PROB †
				BRIGHT AMBIENT LIGHT				
RED	.018	[illegible]	[illegible]	.006	[illegible]	[illegible]	[illegible]	NS
WHITE	.032	[illegible]	[illegible]	.055	[illegible]	9	[illegible]	NS
GREEN	.018	.007	.027	.019	.01	9	[illegible]	NS
CONTROL	.017	.005	.029	.024	.01	9	1.78	NS
				DIM AMBIENT LIGHT				
RED	.044	[illegible]	.037	[illegible]	[illegible]	[illegible]	-.04	NS
WHITE	.020	.007	.052	.045	.03	9	[illegible]	<.05
GREEN	.021	.009	.042	.044	.02	9	[illegible]	NS
CONTROL	.021	.007	.052	.036	.02	9	2.35	<.05

*The analysis was performed using Biomedical Computer Program 3D.

†The P<.05 level was used to determine statistical significance.

Flash Color. The results of a 3-factor ANOVA to determine the effects of flash color and light level on pre- and post-flash horizontal SD error scores are summarized in Table 3. (Because of the observed absence of statistical significance in the pre-post t-tests with control trials, control results were omitted in the present analysis.)

TABLE 3

Summary of Analysis of Variance for Standard Deviation
of Horizontal Error Scores:
Effects of Flash Color and Light Level on
Pre-Post Mean Error Differences *

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	F	PROBABLILITY +
Mean	1	[illegible].31610	180.66	<.001
Error	9	.04[illegible]		
Light Level	1	1.30804	33.88	<.001
Error	9	.03920		
Flash Color	2	.00296	.31	NS
Error	18	.00945		
Light x Color	2	.01748	1.24	NS
Error	18	.01480		
Pre-Post Differences	1	.77056	20.12	<.01
Error	9	.03830		
Light x Pre-Post	1	.10884	5.29	<.05
Error	9	.02057		
Color x Pre-Post	2	.00280	.20	NS
Error	18	.01422		
Light x Color x Pre/Post	2	.00665	.27	NS
Error	18	.02442		

*The analysis was performed using Biomedical Computers Program 2V.

+The P<.05 level was used to determine statistical significance.

As expected, the ANOVA revealed significant main effects for both ambient light level and pre/post SD scores. In addition, statistical significance was found for the pre/post x light level interaction. This latter finding, predictable from an inspection of Figure [illegible], is readily explained by the increased subject horizontal SD error scores associated with post-flash, low-light performance. No significant effects were found for flash color or any interactions containing flash color. An additional ANOVA was performed to determine the effects of flash color and light level on pre/post mean SD difference scores. Although not shown, both the flash color main effect and flash color X light level interaction were non-significant. Thus, under the present test conditions, utilizing a relatively achromatic, high contrast target-background array, low-level red, green, and white flashes were equally effective in producing increased horizontal variable error tracking rates.

Analysis of Tracking Error. The horizontal SD error scores utilized in the previous analyses summarize operator variability around an average point of aim. Large excursions of the tracker's crosshairs are translated into relatively higher variable error scores. Although providing a useful measure of overall error level, additional analyses of operator performance can also be achieved by directly assessing the pre- and post-flash values of the tracking error, i.e., the actual raw digitized scores which represent the operator's deviations from the tank's central aiming point.

Initial aiming error in response to flash. Tracking performance curves for all ten volunteers under the bright light/white flash and low light/green flash conditions are presented in Figures 4a and b. The data shown indicate the horizontal position of the operator's crosshairs with respect to target center and are representative of all the volunteer/light level/flash color conditions. These curves are similar to those presented in Figures 1a-f except that they have been combined for all subjects and redrawn to a common origin (flash onset). In addition, each point of inflection represents the average aim point of a 0.5 sec interval ranging from -2.0 sec pre- to +5.0 sec post-flash.

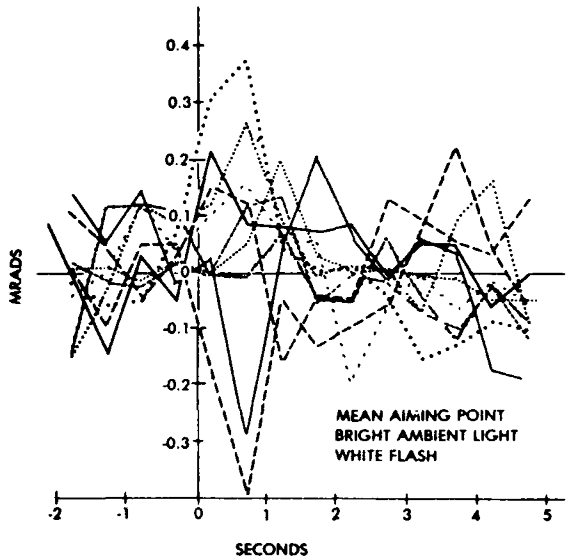

Figure 4a. Individual tracking performance: Bright ambient light - white flash.

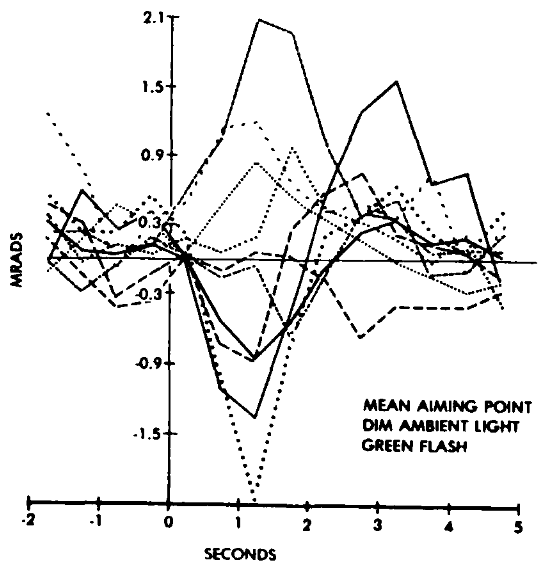

Figure 4b. Individual tracking performance: Dim ambient light - green flash.

While Figures 4a and b express group performance in a somewhat complex manner, even casual inspection of the curves indicates that the onset of the flash (0 sec) generally results in either initial lead or lag errors (crosshairs ahead or behind target, upward or downward deflection of the curves, respectively). Overall, approximately equal numbers of trials displayed, although to different degrees, both types of response to flash occurrence (Bright light: [illegible] lead error, 50% lag error; Dim light: 40% lead error, 40% lag error). A small number of trials, about 1[illegible]% of the total, displayed little discernible error. Small, localized afterimages were reported under low-light conditions, but of an areal extent much smaller than that of the target. Their temporal persistence was fairly brief ([illegible] sec) and had no observable effect on subsequent non-flash trials. Visual monitoring of operator performance, along with subjective reports by some of the volunteers, also revealed the occurrence of "startle" reactions to the onset of the flash. These were usually characterized by a brief excursion of the crosshairs in the direction of target travel, typically resulting in a lead error. Conversely, often in response to the flash, volunteers were inhibited in their pursuit of the target. Corrections to their ensuing lag errors were [illegible] accompanied by small target overshoots before a resumption of pre-flash tracking error levels. Scaling differences in Figures 4a and b once again indicate that these flash effects were of a greater magnitude and duration under the dim ambient lighting condition than under the bright.

Maximum Absolute Error. Distributions of maximum errors, i.e., the maximum deviation of the crosshairs from target center during the 2.0-sec pre-flash and 5.0-sec post-flash epochs are presented in Figures 5a and b for the individual flash conditions under both bright and low-ambient light conditions. Since lead and lag errors ultimately resulted in similar consequences -- decentered or off-target aim -- all the tracking errors are expressed as absolute values. Individual scores are shown by filled circles, range limits are expressed as the top- and bottom-most scores, and sample means are shown by the horizontal lines within the range bars. One post-flash maximum error value for both the white and green flash condition under low-light extended beyond the system's recording capability (+2.5 mrad) and, for purposes of data presentation, it was assigned a value of 2.5 mrad (as shown by the asterisks for the white and green post-flash sample distributions in Figure 5b). The horizontal dashed lines at 0.25 mrad in Figure 5a and at 2.00 mrad in Figure 5b represent, respectively, the limits of the target board and the front/rear end of the tank from the operator's central aiming point. (Because of the target boards' center-of-mass position along the tank's turret ring, the angular subtense is slightly unequal from target center to the front [1.85 mrad] and rear [2.15 mrad] ends of the tank. The 2.00 mrad value, therefore, represents a "compromise" between these two extents.) Scaling differences along the vertical axes underscore the influence of ambient light level on overall performance.

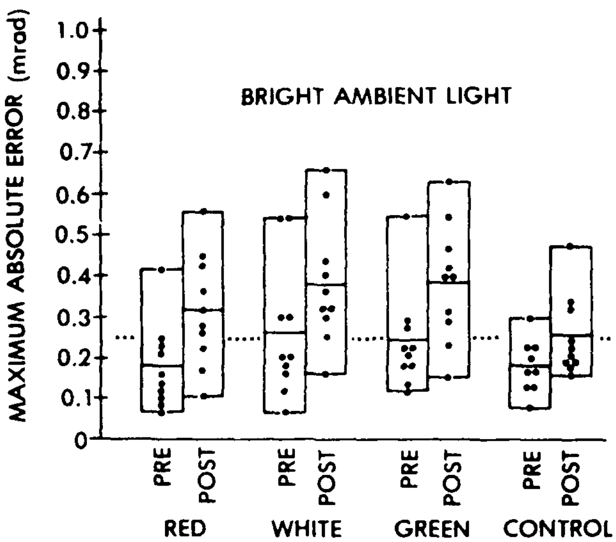

Figure 5a. Maximum absolute error: Bright ambient light.

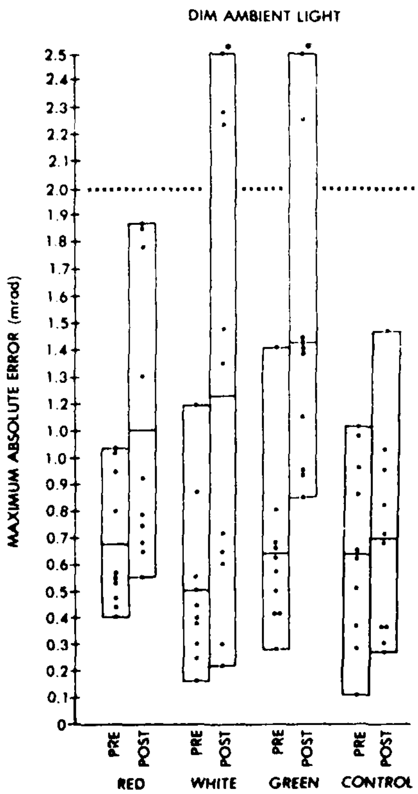

Figure 5b. Maximum absolute error: Dim ambient light.

T-tests for correlated samples were performed to test for the significance of maximum absolute error pre- post mean differences for the flash and control conditions showed that under bright light, statistical significance was achieved for the red ($\bar{d}$=[illegible], df=[illegible], t=4.8[illegible], p<.0[illegible]) and green ($\bar{d}$=[illegible], df=[illegible], t=[illegible], p<.0[illegible]) flash conditions. Under dim light, [illegible] pre-post differences reached statistical significance for all but the control condition (red flash: $\bar{d}$=.42[illegible], df=[illegible], t=[illegible], p<[illegible]; green flash: $\bar{d}$=[illegible], df=[illegible], t=[illegible], p<.0[illegible]; white flash: $\bar{d}$=[illegible], df=[illegible], t=[illegible], p<.0[illegible]). Under bright ambient light, while [illegible] statistically significant post-flash [illegible] absolute errors, [illegible] relatively [illegible] Figure [illegible] shows that, [illegible] deviations of the [illegible] the limits of the [illegible] board. In fact, a plot of post-flash maximum errors along the [illegible] would indicate that the operators' points of aim [illegible] exceeded the boundaries of the target. [illegible] deflections, [illegible] variable error were [illegible] greater under the [illegible] ambient lighting condition. The [illegible] amplitudes of post-[illegible] error [illegible] under low-light most likely [illegible] (and therefore the increased effectiveness of the [illegible]) the difficulty level of the [illegible] under the dim [illegible] conditions. Nevertheless, the majority of the maximal [illegible] along the azimuth following the flash were confined to within the fore-and-aft limits of the tank.

Temporal recovery of flash effects. The curves in Figure [illegible] and b represent the average absolute aiming errors for all the flash conditions under bright and dim ambient lighting. Curves were [illegible] with flash onset as a common origin and with points of inflection representing 0.5-sec group averages from -2.0 sec pre-flash to [illegible] sec post-flash. All the values are expressed as positive numbers irrespective of their derivation from either lead or lag errors.

The effects of flash can be seen as an abrupt but transient increase in aiming error with an eventual return to baseline error levels. Because the points on each of the curves represent the average deviation over 0.5-sec intervals for each subject averaged over all subjects, the actual heights of the curves present a somewhat conservative estimate of the actual magnitude of the aiming error. However, the time course of flash recovery is readily apparent by this approach. For both ambient light conditions, error amplitude peaked fairly rapidly (1-2 sec post-flash), although there was a marked difference in the overall error magnitiude in the two light levels. Return to baseline error levels occured in bright light within 2 sec; under low light, recovery was extended but complete by 4 sec for all flash conditions.

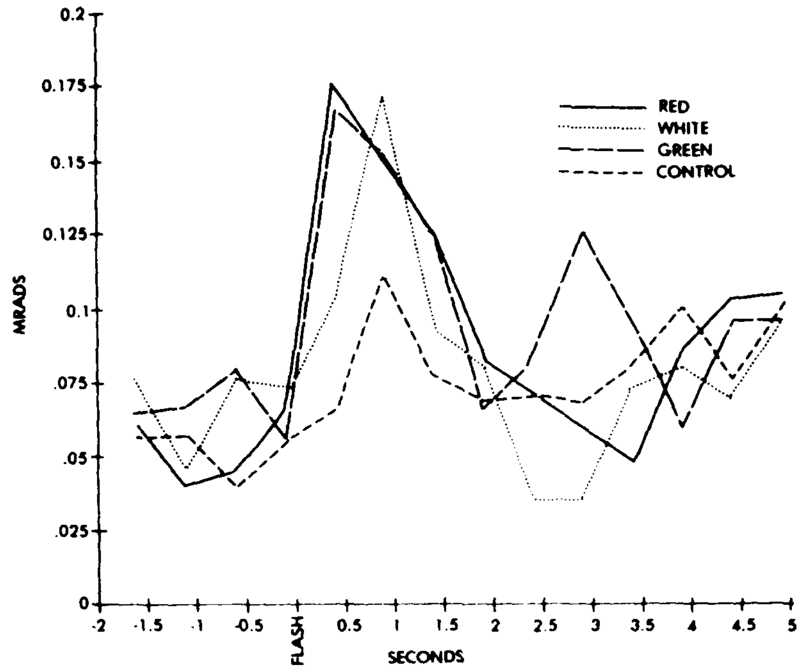

Figure 6a. Average absolute aiming error: Azimuth - Bright ambient light.

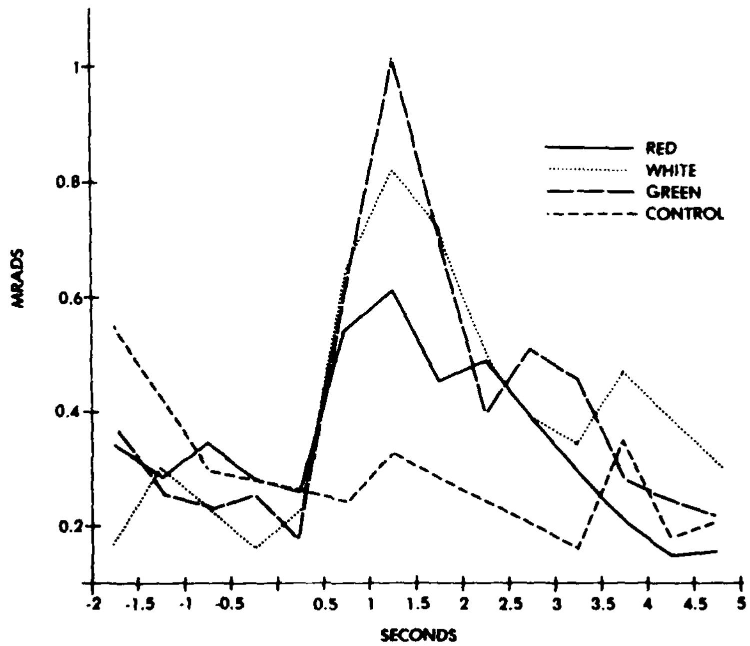

Figure 6b. Average absolute aiming error: Azimuth - Dim ambient light.

DISCUSSION

The effects of simulated laser exposure on pursuit tracking performance were investigated. Repetitive, non-coherent, small-spot, white light and chromatic flashes produced statistically significant increases in horizontal SD tracking error. These were manifested mainly by initial lead or lag errors (crosshairs ahead or behind target) in response to the flash and followed by a return to pre-flash performance levels. The magnitude of the effect was greater under the dim viewing condition than under the bright, as measured by both the maximum aiming error as well as by the temporal course of recovery. However, under dim viewing conditions, the flash frequently resulted in the presence of afterimages and in the elicitation of startle reactions, both of which could have contributed to the increased performance decrement observed under this condition. Such effects could be expected under conditions of partial dark adaptation where the pupil was dilated and there was a concomitant increase in retinal sensitivity. No significant effect was seen for flash color - red, white, and green flashes of equal energy producing equivalent post-flash performance changes - although analyses of the timing errors under low light (Figures 5 and 6) suggest that the red flash may have resulted in a smaller tracking decrement than either the green or white (the latter comprising the entire visible spectrum). Although speculative, such findings would provide confirmation to the subjective reports elicited from the volunteers regarding the differences in the observed apparent brightnesses between the red and the other flashes and would be in agreement with the results expected from a consideration of the standard CIE observer curve (11).

Investigators (5) utilizing the BLASER apparatus under similar experimental conditions previously found that single 538 nm - centered flashes, of radiant energy equal to that used in the present study, consistently produced large disruptions in pursuit tracking performance. That study, however, included a full-field flash whose onset resulted in a protracted series of afterimages, partially obscuring both the entire target and surrounding terrain for several seconds and often persisting into the next non-flash trial. In addition, flashes were frequently accompanied by large startle reactions, which further contributed to the frequently observed off-scale crosshairs deflections. Retinal spot-size in the present study was limited to 100μ, visibly just barely filling the area occupied by the bull's-eye of the target board. Reported afterimages, primarily confined to the dim viewing condition, were generally brief, small, and rapidly resolved. Indeed, at no time was even the target board obscured either by the flash or the ensuing afterimage. In addition, analyses of the data and reports from the volunteers suggest that the overall startle valence of the flash in the present study, again primarily confined to low-light trials, was much reduced in comparison with the observed effects in the previous study (5). Unlike the findings in that study, no clear trends indicating a reduction in flash effective-

ness with repeated exposures could be detected. Thus, disparities in the two studies may reflect differing degrees of physiological and psychological impact related to both the site and specificity of retinal exposure.

It has been stated that the effects of flash can be assessed properly only by its consequences upon performance and that such effects are task specific (12). Under conditions of the present study, therefore, the small-spot flash resulted in performance changes that were only minimally salient under photopic viewing conditions. While it is tempting to speculate on the "tactical" implications of these findings, a precise extrapolation of these data to the "real world" is difficult due to the constraints imposed by the laboratory simulation. Thus, while the tracking error rates produced in the simulation are representative of those produced utilizing currently fielded devices (13), the actual relationship between performance required in the laboratory to that in the field remains unknown. Such factors as target predictability (e.g., angular velocity and direction of movement) and benign operating conditions, while useful for a laboratory tracking simulation, may not provide conditions typical of a combat environment. Increased complexity of target motion, variability of target size, and viewing and operating conditions which take into account varying conditions of visibility, contrast, and noise, could result in less efficient tracking and more pronounced flash effects. Finally, a wealth of bioeffects data, gleaned from both human accident literature (14) and studies utilizing primate animal models (15,16), suggest that directed energy radiation from laser sources, due to its special coherency, energy density, pulse duration, and ultrafast delivery properties, may produce effects much more functionally disrupting than those produced by any broad-band source. Because of all of these factors, the effects of small-spot, non-coherent flashes on pursuit tracking performance observed in the present study should be considered conservative.

CONCLUSIONS AND RECOMMENDATIONS

This study used repetitive, small-spot (100 μ), non-coherent flashes, an order of magnitude below maximum permissible safe exposure levels and much farther below levels characteristic of military laser devices, to assess pursuit tracking performance to large and predictably moving targets in the PLASER simulator. A series of 5 red, white, and green flashes, presented at a rate of 20 Hz, resulted in increased horizontal SP error under bright and dim-ambient viewing conditions. Under low-light, the effects of the flash were characterized by both an afterimage and startle, resulting in a greater overall error magnitude and longer recovery times under this condition. Flash effects were attenuated considerably under bright light.

Future studies will incorporate the presentation of optical countermeasures with evasive target maneuvers. A range of flash brightnesses will be tested and an attempt made to correlate flash energy with effects upon performance. Similarly, flash effects will be evaluated under a range of ambient light levels to elucidate potential mechanisms relating peformance to varying states of retinal adaptation. Future work should also be aimed at investigating the relationship between the site and specificity of retinal exposure and tracking effects. In addition, the role of startle and environmental stress should be evaluated. Currently studies are planned to test many of these variables under field conditions utilizing the with trained line unit operators using the TOW tracking device.

REFERENCES

1. Fereri JD. A review of research on flash blindness. San Francisco, CA: US Navy Radiological Defense Laboratory, 196[illegible]; Report USNRDL-TR-68-76.

2. Williams DW, Duggar BC. Review of research on flashblindness, chorioretinal burns, countermeasures, and related topics. Washington, DC: Defense Atomic Support Agency, 1965; Report No. DASA-[illegible].

3. Keller JE. Lasers on tomorrow's battlefield. Military Intelligence 1981;7:39-43.

4. Stuck BE. Multiwavelength laser threat. In: Combat Ocular Problems. San Francisco, CA: Letterman Army Institute of Research, October 1981.

5. O'Mara PA, Stamper DA, Lund DJ, and Beatrice ES. Chromatic strobe flash disruption of pursuit tracking performance. San Francisco, CA: Letterman Army Institute of Research, 1980: Institute Report No. 88.

6. Sliney D, Wolbarsht M. Safety with lasers and other optical sources. New York, NY: Plenum Press, 19[illegible];101-1[illegible].

7. O'Mara PA, Stamper DA, and Lund DJ. A microcomputer-controlled video system for measuring human pursuit tracking performance. San Francisco, CA: Letterman Army Institute of Research, 1981: Institute Report No. 90.

8. TB MED 279. Control of hazards to health from laser radiation. Washington, DC: Department of the Army, 197[illegible].

9. Dixon WJ, Brown MB, eds. Biomedical computer programs, p-series. Los Angeles, CA: University of California Press, 1979.

10. Stamper DA, O'Mara PA, Beatrice ES, and Lund DJ. Tracking performance with a viscous-damped mount under simulated conditions of varied ambient light levels and target velocities. San Francisco, CA: Letterman Army Institute of Research, 1980: Institute Report No. 82.

11. The Committee for Photometry. Principles of light measurement. International Commission on Illumination. Publication CIE No. 18 (E-1.2) 1970.

12. Randolph DI. Flash effects on the eye: Known and unknown variables reducing visual sensitivity. In: Beatrice ES, Penetar DM. Handbook of laser bioeffects assessment: Bioeffects data (vol 1). Presidio of San Francisco, CA: Letterman Army Institute of Research 1984 (in press).

13. Cheever HL. Human tracking performance using lightweight viscous-damped mounts. Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory, 1977; Technical Memorandum 27-77.

14. Boldrey EE, Little HL, Flocks M, Vassiliadis A. Retinal injury due to industrial laser burns. Ophthalmology 1981;88:101-107.

15. Robbins DO, Zwick H, Holst G. Functional assessment of laser exposure in awake, task-oriented rhesus monkeys. Mod Probl Ophthalmol 1974;13:284-290.

16. Zwick H, Bedell RB, Bloom K. Spectral and visual deficits associated with laser irradiation. Mod Probl Ophthalmol 1974;13:299-306.

February 198[illegible] [illegible] Reg 70-25

VOLUNTEER AGREEMENT
(Military Personnel)

I, ______________________________, having full capacity to consent, do hereby volunteer to participate in a research study entitled "Work Unit ELO[illegible]: Military Stress and Combat Effectiveness: Study 6: Antipersonnel Optical Countermeasures: Experiment [illegible]: The Effects of Repetitive, Small-Spot, Incoherent Flashes on Pursuit Tracking Performance."

The implications of my voluntary participation; the nature, duration, and purpose; the methods and means by which it is to be conducted; and the inconveniences and hazards which may be reasonably expected have been explained to me by ____, and are set forth on the reverse side of this agreement, which I have initialed. I have been given an opportunity to ask questions concerning this investigational study, and any such questions have been answered to my full and complete satisfaction.

I understand that I may withdraw at any time during the course of this study revoke my consent and withdraw from the study without prejudice; however, I may be required to undergo certain further examinations if, in the opinion of the attending physician, such examinations are necessary for my health or well being.

I understand that I shall not be entitled to any payment for my participation.

_________________________________ ______________
Signature Date

I was present during the explanation referred to above, as well as the volunteer's opportunity for questions, and hereby witness his signature.

_________________________________ ______________
Witness' Signature Date

APPENDIX

VOLUNTEER AGREEMENT
(Civilian Adults

I, ______________________, having attained my ________ birthday, and otherwise having full capacity to consent, do hereby volunteer to participate in an investigational study entitled: T-1: Antipersonnel optical countermeasures. EX-1: The effects of repetitive, small-spot, incoherent flashes on pursuit tracking performance under simulated field conditions. The implications of my voluntary participation; the nature, duration, and purpose; the methods and means by which it is to be conducted; and the inconveniences and hazards which may be reasonably expected have been explained to me by ______________________, and are set forth on the attachments to this Agreement, which I have initialed. I have been given an opportunity to ask questions concerning this investigational study, and any such questions have been answered to my full satisfaction.

I understand that I may at any time during the course of this study revoke my consent, and withdraw from the study without prejudice; however, I may be requested to undergo certain further examinations if in the opinion of the attending physician, such examinations are necessary for my health or well being.

I understand that I shall not be entitled to any payment for my participation.

I understand that any time spent participating in this study during my regularly scheduled duty hours will be considered as constructive duty for which straight time rates shall be payable. I further understand that any time spent participating in this study during other than my ragularly scheduled duty hours, or while in a leave status, will be considered as voluntary overtime for which no payment may be made nor compensatory tome be granted.

______________________________ ____________
Signature Date

I was present during the explanation referred to above, as well as the volunteer's opportunity for questions, and hereby witness his signature.

______________________________ ____________
Signature Date

PRIVACY ACT STATEMENT
VOLUNTEER AGREEMENT AFFIRMATION

AUTHORITY

Section 301 of Title 5, U.S. Code; Section 3101 of Title 44, U.S. Code; Sections 1071-1087 of Title 10, U.S. Code; and Executive Order 9397.

PRINCIPAL PURPOSE(S)

The purpose for requesting personal information is to provide the various types of data needed to satisfy the scientific objectives of the study and to provide the minimum information necessary should you require medical treatment at any future time for a condition proximately resulting from your participation in this investigational study, or so that steps can be taken to contact you should it later be deemed in your best interests to do so.

ROUTINE USES

This information will be used to determine the normal values for new vision tests that will be used to screen military personnel and others who build lasers or participate in field exercises where laser systems are employed. The information may also be used to provide full documentation of investigative studies; conduct further research; teach; compile statistical data; adjudicate claims and determine benefits; and report medical conditions required by law to other Federal, state and local agencies. It may be used for other lawful purposes, including law enforcement and litigation. Even though permitted by law, whenever possible, this personal data will not be released without your consent.

MANDATORY OR VOLUNTARY DISCLOSURE AND EFFECT ON INDIVIDUAL NOT PROVIDING INFORMATION

The disclosure of requested information is voluntary. If the information is not furnished, and/or not available from other sources, your voluntary participation in this study may be precluded.

I understand that a copy of the Volunteer Agreement, together with a copy of this form, may be placed in my health records as evidence of this notification, and that additional copies may be retained permanently by the investigator and by the U.S. Government. I have received or have declined to accept a copy of the Volunteer Agreement and a copy of this form which I may keep.

____
Signature

APPENDIX A (cont)

EXPLANATION OF QUESTIONS RELATING TO

VOLUNTEER AGREEMENT

1. What will be administered or done to the volunteers:

Prior to beginning the study you will be given an eye examination to determine if you have normal visual acuity, dark adaptation, and color vision. After the eye examination you will be asked to participate in a series of tracking sessions. During each session you will be asked to be seated in a dimly lighted sandbag room and asked to accurately aim at track moving targets through a sighting scope in a laser designator device.

2. How long will your participation last?

Your participation will include an eye examination, three training sessions each of which will last approximately 1 hr and 15 min and one test session that will be comprised of 32 15-sec trials that will last approximately the same length of time.

3. To what tests or examinations will I be required to submit?

a. Before being accepted into the study, you will be asked to take an eye examination that includes visual acuity, dark adaptation, color vision, and visual inspection of your eye be a physician.

b. During the study you will be asked to participate in several (3 to 5), 45 minute sessions. During each session you will track targets with an optical tracking device and your performance of this task will be measured. Each tracking session will be scheduled on a separate day.

4. Why is the investigation being conducted?

With the increased use of optical devices for ranging and tracking in the military, information is required concerning physiological and behavioral factors which influence the soldiers ability to use these devices. Guidelines that will maximize the likelihood of a successful mission using these devices should be established under conditions that are highly similar to those expected during combat. Such data can be used for training of troops in the field.

APPENDIX A (cont)

5. Has this particular study been done previously, and if so with what results?

No.

6. What inconveniences or discomforts will I likely experience?

During the practice and test sessions you will be asked to spend approximately 2 hrs total in a semi-darkened sanbag bunker. During this session, you will be asked to track a moving target for periods up to 20 sec. Rest periods will be included where necessary to prohibit the development of fatigue. Considerable attention on your part will be required to insure valid tracking data. During some of the tracking trials you will be exposed, without warning, to brief flash of light. The flash is not hazardous. The flash effects that you will experience are similar to those produced by a standard photographic flash attachment. These effects include reflex eyeblink, temporary loss of dark adaptation, and brief appearance of visual afterimages. These flash effects are temporary and will last for only a short period.

7. What risks or hazards can be reasonably anticipated?

None.

8. What steps will be taken to prevent or minimize these risks or hazards?

Not applicable.

9. What benefits, if any, may I expect from my participation in the study?

Some of the eye examination information may be useful for you.

10. What appropriate alternative procedures, if any might be more advantageous to me?

None.

11. How will my records and data be stored?

All records and data will be stored in a confidential file within the Division of Ocular Hazards, LAIR, PSF. Only project personnel will have access to this file.

APPENDIX A (cont)

12. Where can medical treatment be received in the event that it is necessary?

Medical treatment can be received in the Visual Functions area of the Division of Ocular Hazards and also at Letterman Army Medical Center.

13. Who can be contacted in reference to the research being conducted, subjects rights, and research related injuries?

CPT Levine, Mr. David Stamper or COL Beatrice can be contacted for any of the above information. They can be reached at [illegible]-3344/3376, Division of Ocular Hazards, LAIR, PSF.

14. What are my obligations to the project?

Once you have begun the project, we would like you to complete your part of the project since time alloted for you is valuable to us and would add considerably to the total length of the study if even just a few of these participants did not complete their part of the project. However, you may revoke your consent at any time and withdraw from the project without prejudice.

15. What is the title of the study, where will it be conducted and who is the principal investigator?

The title of this study is The Effects of Repetitive, Small Spot Incoherent Flashes on Pursuit Tracking Performance. The study will be conducted within the Division of Ocular Hazards, Letterman Army Institute of Research, Presidio of San Francisco. The principal investigator will be CPT Richard E. Levine.

Richard E. Levine, PhD
CPT, MSC
Research Psychologist
Division of Ocular Hazards
(415-561-3376)
Principal Investigator

Edwin S. Beatrice, M.D.
COL, MC
Division of Ocular Hazards
(415-561-3344)
Responsible Physician

APPENDIX A (concluded)

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Aberdeen Proving Ground MD 21070

US Army Research Office
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Division
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Director of Life Sciences
USAF Office of Scientific Research (AFSC)
Bolling AFB
Washington DC 20332

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Walter Reed Army Institute of Research
Washington DC 20012

Commander
US Army Medical Research Institute
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Naval Medical Research Institute
National Naval Medical Center
Bethesda MD 20014

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USAF School of Aerospace Medicine
Aerospace Medical Division
Brooks Air Force Base TX 78235